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The post mortem examination of ruminants and its possible benefit to clinical ruminant medicine

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Zusammenfassung

Diese Arbeit hat zum Ziel, die Rolle der pathologischen Sektion von Wiederkäuern und ihren Nutzen für die Wiederkäuermedizin darzustellen. Dazu wurden klinische und pathologische Diagnosen verglichen und Faktoren, welche die Qualität der Sektion beeinflussen identifiziert. Retrospektiv wurden 2000 Krankenakten von Wiederkäuern ausgewertet, welche am Institut für Veterinärpathologie der Universität Zürich seziert wurden. Klinische und pathologische Diagnosen waren in 81,40% der untersuchten Rinder, 80,22% der Schafe und 66,66% der Ziegen vorhanden. Keine Diagnosen wurden in 3,86% der Rinder, 3,30% der Schafe und 7,41% der Ziegen gefunden. Den größten Einfluss auf das Vorhandensein von Diagnosen hat die Todesart, die Art der Sektion und das Alter. Die klinische Hauptdiagnose konnte in 86,20% der Rinder, 85,51% der Schafe und 82,00% der Ziegen bestätigt werden, in 7,03% der Rinder, 12,26% der Schafe und 11,00% der Ziegen konnte sie nicht bestätigt werden. Relevante Zusatzinformationen oder Spezifizierungen wurden bei 70,87% der Rinder, 45,21% der Schafe und 56,66% der Ziegen gefunden. Der Grad der Übereinstimmung und die Spezifizierung der Diagnosen wurde beeinflusst durch die Todesart, die Art der Sektion, die Durchführung einer histologischen Untersuchung und die Aufklärung eines vorberichtlichen Bestandesproblems. Diese Studie konnte die wichtige Rolle der Sektion in der modernen Wiederkäuermedizin darstellen, sowohl in der Diagnostik als auch in der Qualitätssicherung.

Abstract

To highlight the important role of post mortem examination of ruminants and to identify possible benefits for modern ruminant medicine, a comparison of clinical and pathological diagnoses was conducted and influencing factors were identified. For this purpose, 2000 ruminants that had undergone necropsy at the University of Zurich, Switzerland were analyzed retrospectively. Both diagnoses were available in 81.40% of cattle, 80.22% of sheep and 66.66% of goats; no diagnoses were available in 3.86% of cattle, 3.30% of sheep and 7.41% of goats. In the remaining cases, either the pathological or the clinical diagnosis was unavailable. The greatest influence on the presence of diagnoses was the type of death of the animal, the type of necropsy and the animal's age. The majority of diagnoses were attributed to digestive and respiratory disorders in cattle and digestive, neurologic and urinary disorders in small ruminants. The main clinical diagnosis could be confirmed pathologically in 86.20% of cattle, 85.51% of sheep and 82.00% of goats, whereas 7.03% of diagnoses in cattle, 12.26% in sheep and 11.00% in goats could not be confirmed in the post mortem / histopathological examination. Relevant additional information or specification of diagnoses was given in 70.87% of cattle, 45.21% of sheep and 56.66% of goats. The concurrence of diagnoses and diagnosis specification were most influenced by the type of death of the animal, the type of necropsy that was conducted, the performance of a histological examination following the necropsy and whether the animal was submitted in connection with a livestock health problem. This study was able to show the important role of the post mortem examination in modern ruminant medicine, as a tool in both diagnosis making and quality control.

Introduction

The post mortem examination of domestic animals has played an important role in veterinary diagnostics for centuries and has been conducted on a regular basis since Rudolph Virchow (1821-1902), who can be regarded as one of the founding fathers of the "One health – one Medicine" idea and modern human and veterinary pathology, encouraged the introduction of meat inspections in abattoirs in Germany (Cardiff et al., 2008) to systematically identify and control epizootic diseases. Today, this key role in quality control and disease monitoring is unchallenged. In addition, necropsies have proved themselves to be an invaluable tool for clinicians and students, because of their importance in complementing clinical medicine by confirming, refuting or augmenting pre-mortem diagnoses (Law et al., 2012 and http://www.acvp.org). Over the last decades, cattle mortality has been rising throughout Europe and the US (Alvåsen et al., 2012, Miller et al., 2008 and Thomsen and Houe, 2006), and it could be shown that non-infectious diseases were causative for the majority of deaths Bascom and Young, 1998, Esslemont and Kossaibati, 1997, Miller et al., 2008, Svensson et al., 2006, Thomsen and Houe, 2006 and Watson et al., 2008). The main reasons why domestic animals are submitted to necropsy nowadays are primarily to determine the cause of unexplained death of individual animals or the cause of suddenly increased mortality rates in herds, and only secondarily for its original purpose of detecting potentially epizootic or zoonotic diseases in livestock. However, a literature review of 19 studies dealing with cattle mortality conducted between 1965 and 2006 revealed that in none of these studies the diagnoses were based on necropsy results, but on clinical diagnoses made prior to death by veterinarians or farmers (Thomsen and Houe, 2006). Considering this fact, the question arises as to what extent those diagnoses could have been confirmed or refuted by a post-mortem examination. In the meantime several studies have been published that tried to underline the value of post-mortem / histopathological examination as a diagnostic tool and to evaluate the concurrence between pre-mortem and post-mortem diagnoses in veterinary medicine. One study evaluated the death of 94 animals from a dairy herd in Colorado, determining a cause of death in 96% of cases, whereas the concurrence of pre-mortem and post-mortem diagnoses was given in 55% (McConnel et al., 2009). Another study evaluating the death of 79 cows revealed a likely cause of death in 97%, agreement

of diagnosis being reached in 25% to 28% of the cases. Thomsen et al., 2012, and a study conducted at an incineration plant (Watson et al., 2008) revealed a cause of death in 48% of 253 examinations, but this study included only cattle dying unexpectedly or found dead without prior veterinary examination. All studies revealed that in many cases post mortem examination could provide valuable information on the cause of death.

In small animal medicine, additional studies were identified that analyzed the value of post mortem examination, all of which were conducted at veterinary teaching hospitals (Dank et al., 2012, Kent et al., 2004 and Vos et al., 2005) and had a special focus on the development of disagreement rates over several decades. These studies revealed a rate of agreement of pre-mortem and post-mortem diagnoses between 51.3% and 85.1% and disagreement in 14.9% to 39.8% of all cases, depending on the decade analyzed. A recent retrospective study conducted at the University of Zurich on 2000 dogs and cats identified disagreement in 17.9% of cats and 16.0% of dogs, and revealed the important role of the pathological examination as a diagnostic tool in solving clinically unclear cases and giving relevant additional information regarding specific diagnoses, like tumor classification (Schertenleib et al., 2015). In human medicine, by comparison, where many studies have been conducted regarding the concurrence of clinical and pathological diagnoses, error rates between 4.1% and 49.8% were revealed, with a median rate of 23.5% (Scott et al., 2010). In the current study, for the first time, a large-scale examination of pre-mortem and post-mortem diagnoses of domestic ruminants, which had received diagnostic examination and clinical treatment at a veterinary teaching hospital was conducted. The first aim was to describe and analyze whether diagnoses were made in each case and which factors influenced the performance of diagnoses. Second, it was to highlight the concurrence of pre- and post-mortem diagnoses and whether further specifications of diagnoses and additional relevant information could be given in necropsy and which factors influenced this process.

Material and methods

Study setting

For this retrospective study, clinical and pathological records of ruminants were reviewed that were submitted for post mortem examination to the Institute of Veterinary Pathology, Vetsuisse Faculty, University of Zurich (IVPZ) by the Clinic of Ruminants, Department for Farm Animals, Vetsuisse Faculty, University of Zurich. Both institutions are part of a veterinary teaching hospital, therefore junior veterinarians under supervision of experienced senior staff members performed clinical examinations as well as necropsies. The patients' charts were on hand as hand- or typewritten documents and included the results of the clinical examination, diagnoses, treatment and reports of possible additional examinations. The results of the post mortem examination were noted in a standardized necropsy protocol, including gross findings, histological findings if conducted, pathological diagnoses and, usually, a comment. Cases were reviewed until a predetermined number of 2000 evaluable cases were reached, according to the inclusion and exclusion criteria defined below. To achieve this, 3139 cases submitted for necropsy between January 2007 and July 2013 had to be inspected, giving a rate of 63.71% analyzable cases.

Inclusion and exclusion criteria

Only animals having received basic clinical examination prior to death or euthanasia or having undergone clinical treatment were included, thus excluding animals that died during examination or arrived dead at the clinic. Abortions and stillbirths were therefore not considered, nor were wild living ruminants, camelids, and animals that were part of research projects. Cases in which either the patient's health record or necropsy report was missing, incomplete or incomprehensible were also excluded. Partial necropsies were only considered if at least the complete set of internal organs (digestive, urogenital, respiratory and cardiovascular system) was present for post-mortem examination, thus excluding cases in which for example solitary organs or parts of limbs were sent in.

Record reviewing

Species (cattle, with water buffalos being counted as “cattle” for simplification, goat, sheep), breed, sex, type of death (unassisted death, assisted death) and age of the animal were noted. Ages were defined as neonatal until the age of 3 days, juvenile/pre-adult until first calving, lambing or kidding, respectively, and adult because of the established database and not because of physiological/clinical criteria. All cases that were sent in for clarification of a suspected stock problem were noted. Internal numbers of the patient’s medical record and necropsy record were used for identification. The Clinic of Ruminants forms one organizational entity, and is counted as such in the present study, meaning that no differentiation of the sending subdivision (internal medicine, surgical ward, reproductive management) was made.
The patient’s record was reviewed for clinical diagnoses explicitly mentioned as such in the patient’s chart. Suspected diagnoses were not considered. A main diagnosis was identified, if present, being defined as the diagnosis most likely causing the death of the animal or leading to the decision for euthanasia or slaughtering. In addition, up to 3 secondary diagnoses for each case were noted, in an order irrespective of their severity. Secondary diagnoses were defined as not causative for the death or euthanasia of the animal, but which, if taken separately, could have been lethal to the animal or, if untreated, could have caused treatment worthy clinical symptoms and diagnoses that would have had further bearing on the case. As a matter of fact, death or euthanasia is often caused by a sequence of events (McConnel et al., 2009). In such cases, the primary underlying pathological changes, if diagnosed, were taken as the main diagnosis and all afflictions directly caused by this alteration were allocated to the diagnosis (e.g. liver abscess with thrombosis of vena cava and thromboembolic pneumonia, with liver abscess being the primary diagnosis). Each diagnosis was categorized under 2 different schemes, comparable to the method conducted by McConnell et al,. 2009. Main diagnoses were grouped into 14 major categories, following a modification of the system originally used by Thomsen and Houe, 2006.Categories included: cardiovascular-, digestive-, metabolic-, musculoskeletal- respiratory-, neoplastic-, urinary-, reproductive-, udder/teat-, neurologic-, sensory-, musculoskeletal-, systemic- (affection of multiple major categories, mainly septicemia or infections), miscellaneous disorders (diagnosis not relating to any other category) and accidents. The category was again

selected based on the underlying pathological process, if diagnosed (thromboembolic pneumonia due to a liver abscess was therefore counted as digestive disorder). Furthermore the diagnoses were separated into pathophysiological groups based on the problem oriented medical record scheme with the acronym DAMN-IT suggested by Osborne, 2005, with classifications as follows: degenerative, congenital, metabolic, nutritional, neoplastic, inflammatory/infectious (bacterial, viral, parasitic, fungal), inflammatory/non-infectious or unknown, iatrogenic, idiopathic, multifactorial, traumatic, toxic, foreign body and miscellaneous.

Necropsy records were reviewed for main and secondary pathological diagnoses following the aforementioned procedures, and characterizations and additional examinations conducted after necropsy including histology, immunohistochemistry, bacteriology, parasitology, virology and other analyses were noted. It is assumed that the original examination of the cases and the process of making a diagnosis was performed conscientiously and following good medical practice, on the part of the clinician as well as on the part of the pathological examiner. Therefore no reviewing of archived raw data, like lab results or histological slides, was performed.

Case categorization

To indicate whether main clinical diagnoses and main pathological diagnoses could be established, each case was categorized into four groups based on the system used by Vos et al[33] as follows:

Group A: main clinical and pathological diagnoses available

Group B: main pathological diagnosis absent, but main clinical diagnosis available

Group C: main clinical diagnosis absent, but main pathological diagnosis available

Group D: neither main clinical diagnosis, nor main pathological diagnosis

Main clinical and main pathological diagnoses of group A were compared to determine the concurrence and potential specification of diagnoses and grouped into 4 classes comparable to the system implemented by Battle et al[4].

Agreement class 3: total agreement of clinical and pathological diagnosis, with no further specification

Agreement class 2: agreement of clinical and pathological diagnosis, with minor specification in necropsy without clinical pertinence

Agreement class 1: agreement of clinical and pathological diagnosis, with major specification in necropsy of clinical pertinence, regarding previous treatment or the decision for euthanasia, as for example the detection of a specific pathogen that could have been treated, or the detection of the major, clinically unsuspected underlying pathological process directly causative for the main clinical diagnosis (e.g. pneumonia due to a dispersing liver abscess, which was detected in necropsy).

Disagreement: disagreement of main clinical and main pathological diagnosis. Disagreement was defined as a distinction in the major category of main clinical and main pathological diagnoses or, if the major category was the same, the detection of a different, independent underlying pathological process as the cause of the major diagnosis. Disagreement is possible in two situations. The first: the clinical diagnosis was not confirmed and a pathological diagnosis was revealed in necropsy (**disagreement type I**). The second: the clinical diagnosis was not confirmed as the main diagnosis but as a secondary diagnosis, with detection of the main pathological diagnosis in necropsy (**disagreement type II**), e.g. the animal was euthanized due to pneumonia, which was confirmed in necropsy, but a perforating abomasal ulcus with peritonitis was revealed as the main pathological diagnosis. In general, for these analyses the pathological diagnosis was defined as the gold standard (Gutierrez et al,. 2009),, meaning that all analysis was conducted based on the information gained in the post mortem examination.

To highlight the causes for missing main pathological diagnoses, all cases of group B were categorized into 5 groups as follows:

I: main clinical diagnosis not confirmable due to mistakes of clinic or incorrect transmission

II: main clinical diagnosis not confirmed due to mistakes in necropsy or failed inspection

III: main clinical diagnosis not confirmed in necropsy (e.g. abomasal displacement that is no longer present in necropsy due to post mortal events)

IV: main clinical diagnosis not confirmed by means of pathology

V: the main clinical diagnosis was not confirmed, but no main pathological diagnosis was revealed. Therefore, the case remains unsolved.

In conclusion, the number of cases in which the main clinical diagnosis was revealed to be incorrect in the post mortem examination is given by the sum of cases counted as disagreement type I within group A and all cases of category V within group B.

Ambiguous cases were reviewed with a veterinary pathologist (ECVP certified) prior to categorization, where the benefit of the doubt was usually given to the clinician`s side.

Secondary diagnoses were reviewed in a comparable, but limited manner. For each secondary clinical diagnosis it was noted whether the diagnosis was confirmed, not confirmed, not confirmable, or specified in necropsy (if clinically relevant additional information regarding the diagnosis was gained) or if no further examination was conducted. For each secondary pathological diagnosis it was noted whether a corresponding clinical diagnosis existed, a corresponding clinical diagnosis was missing or the diagnosis was a relevant specification of the corresponding clinical diagnosis. For each case linked to a suspected stock health problem it was noted whether any hint in solving the problem could be provided by necropsy (e.g. the detection or exclusion of a specific pathogenic organism in histology).

Data management and statistics

Data management was conducted with a FileMaker Pro 11.0v4, FileMaker, Inc. Santa Clara, CA, USA database and MS Excel spreadsheets. The statistical analyses were done using Stata Software (StataCorp., 2011; Stata Statistical Software: Release 12; College Station, TX, USA: StataCorp LP). Analyses were carried out using the clrchi2 and logistic command. A p-value of ≤ 0.05 was considered significant. In a first approach Pearson's chi squared tests were performed to assess the statistical influence of case characteristics on the presence and concurrence of diagnoses. In a second approach a multiple logistic regression was performed, using a step back procedure. All characteristics showing a tendency (P-value ≤ 0.2) were entered into a full model. The step back procedure was performed according to Altman 1991. Again, a P-value ≤ 0.05 was considered significant and used as the endpoint (final model). Univariate and multivariate analyses were performed to identify all influencing factors on the presence and possible specification of diagnoses. During the analysis it became clear that due to the limited number of sheep and goats used in this study, only limited meaningful results could be gained. Therefore, it was decided to present the results of the descriptive statistics for all species but to limit the results of the univariate and multivariate analyses to cattle.

Results

General overview of species distribution

Altogether the reports of 2000 animals were reviewed, including 1'683 cattle (84.14%), 182 sheep (9.10%) and 135 goats (6.75%). The majority of animals were female, with a distinct differentiation between species (90.61% of cattle, 65.38% of sheep, 64.44% of goats). Most animals were adult (70.05% of cases), followed by juvenile/ pre-adult (27.05% of cases). In 9 cases the age could not be determined. As this study took place in a veterinary teaching hospital, the vast majority of animals died with assistance (89.90% of all cases). A full necropsy was performed on 83.20% of all cases, but it should be considered that many cases that had undergone a partial necropsy do not appear in this study due to the aforementioned exclusion criteria. A detailed overview of cases with species distribution is given in table 1.

Additional examinations:

Adjunctive diagnostics following the post mortem examination were conducted in 64.05% of cases (n=1'281), with a total number of 1'982 solitary examinations. No further examination was initiated in 35.95% of cases (n=718). Histology was performed in 60.65% (n=1'213), bacteriological examination in 19.10% (n=382), immunohistochemistry in 8.80% (n=176), parasitology in 5.55% (n=111), virology in 4.45% (n=89) and other examinations, like toxicology in 0.55% (n=11) of cases.

Established diagnoses and species distribution

In cattle, both a main clinical and main pathological diagnosis (Group A) could be made in 81.40% (n=1'370) of cases. No main pathological diagnosis (group B) was identified in 7.31% (n=123) and no primary clinical diagnosis (group C) was found in 7.43% (n=125). In 3.86% (n=65) neither a main clinical diagnosis, nor a main pathological diagnosis could be identified (group D), and the cause of illness remained unresolved. Therefore, a main clinical diagnosis could be established in 1'493 (88.71%) cases (groups A and B) and a main pathological diagnosis (groups A and C) in 88.83% (n=1'495). A similar picture appeared within sheep with 80.22%

(n=146) of cases in group A, 4.94% (n=9) in group B, 11.54% (n=21) in group C and 3.30% (n=6) in group D. Slightly different numbers arose in goats, with 66.66% (n=90) of cases within group A, 7.41% (n=10) in group B, 18.52% (n=25) in group C and 7.41% (n=10) in group D. A detailed overview including species distribution is given in table 2. The distribution of causes for missing main pathological diagnoses within group B is highlighted in table 3.

Primary categories and pathophysiological groups

As mentioned above, main clinical and main pathological diagnoses were categorized into 14 primary categories and underlying pathophysiological groups. Taking into account the species distribution of main clinical diagnoses in cattle, the majority were assigned to digestive disorders (40.66%) and respiratory disorders (18.89%) for the primary categories and inflammatory (49.97%) and multifactorial (24.25%) for the underlying pathophysiological group. Considering main pathological diagnoses in cattle, the majority of cases were also counted as digestive disorders (42.88%), followed by respiratory disorders (16.92%), with inflammatory (50.73%) and multifactorial (19.78%) for the pathophysiological groups. The distribution of main clinical diagnoses in sheep revealed digestive disorders representing 26.45% of cases, followed by neurologic disorders (22.58%) and urinary disorders (11.61%), with inflammatory (65.81%) and nutritional (10.97%) as predominant pathophysiological groups. A similar picture is shown regarding main pathological diagnoses in sheep, with digestive disorders accounting for 32.34% of cases, followed by neurologic disorders in 14.97% and urinary disorders in 10.18%, and inflammatory (63.01%) and nutritional (13.01%) for the pathophysiological groups. In goats, the distribution of primary categories is comparable to the distribution within sheep, as the majority of main clinical diagnoses were assigned to digestive disorders (26.0%), neurologic disorders (18.0%) and urinary disorders (19.0%), as well as inflammatory (43.0%) and nutritional (29.0%) for the majority of pathophysiological groups. Main pathological diagnoses in goats were most frequently assigned to digestive disorders (27.83%), neurologic disorders (18.26%), urinary disorders (14.78%) and neoplasms (11.30%), with inflammatory (40.0%), nutritional (28.89%) and neoplastic (13.33%) as predominant pathophysiological groups. An overview is given in table 4.

Concurrence of diagnoses and diagnosis specification

In cattle, total agreement with no further specification (agreement class 3) of the main clinical diagnosis and the main pathological diagnosis was given in 20.88% (n=286), referring to all 1'370 cases in group A. In 35.18% (n=482) of cases the post mortem examination revealed a minor further specification of the main clinical diagnosis, without clinical importance (agreement class 2). Further specification of clinical importance (agreement class 1) could be made in 35.69% (n=489) of cases.
Disagreement of main clinical and main pathological diagnoses was given in 8.25% (n=113) of cases, of which in 6.06% of cases (n=83) the main diagnosis was revealed in post mortem examination (disagreement type I) and in 2.19% (n=30) the main clinical diagnosis was confirmed, not as a main diagnosis, but as a secondary diagnosis, while the main pathological diagnosis was revealed during necropsy (disagreement type II). Although there is a disagreement in the main diagnoses, the main clinical diagnosis itself can still be counted as a confirmed diagnosis. In 22 cases from group B the main clinical diagnosis was not confirmed, but no main pathological diagnosis could be made (category V). Taking into account the total number of cases with a main clinical diagnosis (n=1'493), consisting of cases from group A and B, this diagnosis could be confirmed by necropsy in 86.20% (n=1'287) of cases and proved to be incorrect in 7.03% (n=105), given as disagreement type I plus category V (6.77% (n=105) were counted as categories I – IV).
In sheep, 42.47% (n=62) of 146 cases from group A were counted as agreement class 3, 19.18% (n=28) as agreement class 2 and 26.03% (n=38) as agreement class 1. Disagreement was given in 12.33% (n=18), with 8.90% (n=13) counted as disagreement type I and 3.42% (n=5) as disagreement type II. The main clinical diagnosis in sheep was confirmed in 85.81% (n=133) of 155 cases of group A and B but proved to be incorrect in 12.26% (n=19), with 13 cases counted as disagreement I and 6 cases counted as category V (1.93% (n=3) of cases belonging to categories I-IV).
In goats, agreement class 3 was identified in 34.44% (n=31) of 90 cases from group A, 33.33% (n=30) belonged to agreement class 2 and 23.33% (n=21) were counted as agreement class 1. Disagreement was present in 8.89% (n=8) of cases, all of them belonging to disagreement type I. The main clinical diagnosis in goats was confirmed in 82.0% (n=82) of cases from group A and B and could not be confirmed

in 11.0% (n=11), with 3 cases counted as category V and 7.0% (n=5) counted as categories I-IV. An overview including all categories is given in table 5, while table 6 shows the general number of confirmed and unconfirmed diagnoses.

Secondary diagnoses

As mentioned above, in addition to the presence of up to 3 secondary diagnoses, their concurrence and possible specifications were noted and analyzed in a simplified manner. The results are given in table 7.

Influencing factors on the presence of diagnoses in cattle

The univariate analysis revealed that the sex of the animal had no influence on the presence of diagnoses. On the other hand, manner of death, age of the animal, type of necropsy, performance of histological examinations, the primary category of the main clinical diagnosis and its pathophysiological basis all had a significant influence on whether diagnoses were established. Unassisted death had more influence on the distribution than assisted death, resulting in more cases than expected without a clinical diagnosis (group C) or without any diagnosis at all (group D), but at the same time fewer cases with just a pathological diagnosis (group B) or both clinical and pathological diagnoses (group A). Neonatal animals showed the most influence of all age classes, with more cases of group C than expected and fewer cases of group A. The type of necropsy had a strong impact on the presence of diagnoses. Partial necropsies resulted in a much higher number of group B cases than expected, a slightly higher number of group D cases and fewer cases of group A and C. The performance of a histological examination resulted in fewer cases than expected without a pathological diagnosis (group B) compared to cases where no histological examination was conducted. Considering the primary categories of the main clinical diagnosis and the pathophysiological basis of those diagnoses, their impact on the presence of diagnoses could also be determined. For the main clinical diagnosis, neurologic disorders and accidents, (resulting in more cases of group B and fewer of group A than expected) as well as respiratory disorders and miscellaneous disorders (resulting in more cases of group A and fewer of group B), had the most impact on the presence of a pathological diagnosis as did the categories multifactorial,

traumatic (more cases of group B and fewer of group A) and inflammatory (more cases of group A and fewer of group B) for the pathophysiological basis.
The multivariate analysis revealed that the likelihood of occurrence of group A cases was influenced by the animals' cause of death, with assisted death compared to unassisted death (OR 6,85 (4.36, 10.75)) and their age, with adult animals compared to non-adults (OR 0.67 (0.44-0.84)). Inflammatory/infectious as the pathophysiological basic principle of the main pathological diagnosis had a considerable influence as opposed to all other pathophysiological categories (OR 0.92 (0.88-0.96)) as well as the lack of a histological examination compared to the conduction of one (OR 0.69 (0.40-0.97)). The likelihood of occurrence of cases counted as group B (missing main pathological diagnosis) was influenced by inflammatory/infectious as the pathophysiological basis of the main clinical diagnosis as opposed to all other bases (OR 1.07 (1.04-1.11)) and the type of necropsy, where the likelihood was increased for partial necropsies compared to total necropsies (OR 2.87 (1.93-4.29)). Type of death, age and the pathophysiological basis of the pathological diagnosis were identified as influencing the chance of a case of group C (missing clinical diagnosis). The chance was reduced if the animal died an assisted compared to an unassisted death (OR 0.15 (0.10-0.25)), but was increased if the animal was juvenile or neonatal (OR 1.59 (1.14-2.23)) and if the pathophysiological basis of the pathological diagnosis was other than inflammatory/infectious (OR 1.08 (1.04-1.13)). The most influencing factors on the probability of a group D case were type of death, with a increased risk for animals that died an unassisted compared to an assisted death (OR 0.30 (0.16-0.55)) and animals that were not adult (OR 0.50 (0.28-0.89)).

Influencing factors on the concurrence of diagnoses and possible diagnosis specification in cattle

This analysis only considered cases with both a main pathological and main clinical diagnosis (group A). The univariate analysis identified several factors with significant influence on the concurrence and specification of diagnoses, namely type of death, age, assumption of a stock problem, conduction of a histological examination, the type of necropsy as well as the primary category and the pathophysiological basis of the main clinical diagnosis. A strong impact on the expected distribution was made

by the type of death, where a natural death resulted in more cases with disagreement, fewer cases of agreement class 2 (minor additional information gained in necropsy) and slightly more cases of agreement of classes 1 (major additional information discovered) and 3 (no additional information revealed), compared to animals that died an assisted death. For age categories, most discrepancy was revealed for juvenile/pre-adult animals, with far less agreement class 2 than expected, but at the same time more cases of disagreement and agreement classes 1 and 3, compared to adult and neonatal animals. The assumption of a stock problem also had a strong influence on the distribution, resulting in far more cases of agreement class 1 and 2, slightly more cases of agreement class 3 and fewer cases of disagreement than expected. The performance of a histological examination following necropsy resulted in fewer cases of agreement class 2, but more cases of agreement classes 1 and 3 and cases of disagreement. Another influencing factor was the type of necropsy performed. Partial necropsies resulted in fewer cases of agreement class 1 and cases of disagreement, but slightly more cases of agreement classes 2 and 3, compared to cases in which a full necropsy was performed. For the primary category of main clinical diagnoses, noticeable influence was found for respiratory disorders (more agreement class 1, less agreement class 2 and 3), neurologic disorders (more agreement class 3 and disagreement), systemic disorders (more agreement class 2 and less agreement class 1) and miscellaneous disorders (more agreement class 1 and less agreement class 2 and 3 and disagreement). For the pathophysiological basis of diagnoses a striking influence was revealed for the groups idiopathic (less agreement class 1, but more agreement class 2), miscellaneous (more agreement class 1, less agreement classes 2 and 3), metabolic (more agreement class 3) and foreign body (less agreement class 1, but more agreement class 2). The multivariate analysis revealed the factor most influencing the likelihood of occurrence for all classes of agreement and disagreement alike. As for agreement class 1, it was the suspicion of a stock problem (OR 1,57 (1.01-2.26)) compared to cases were no stock problem was suspected. For agreement class 2, several equivalent factors were identified. The type of death had an influence, with a higher probability for animals that died an assisted compared to an unassisted death (OR 1.76 (1.02 – 3.03)). Lower chance for agreement class 2 was given for neonatal and juvenile/pre-adult animals compared to adult animals (OR 0.72 (0.57 – 0.92)), the assumption of a stock problem, compared to the absence of

such problem (OR 0.54 (0.35 – 0.84)) and the performance of a histological examination compared to the lack of it (OR 0.75 (0.50 – 0.94)). The factors mostly influencing the likelihood of occurrence of agreement class 3 were identified as age, with higher probability for all ages except adult (OR 1.65 (1.28 – 2.13)) and for partial necropsies compared to total necropsies (OR 1.68 (1.20 – 2.36)). The performance of a histological examination and the age of the animals were the factors most influencing the likelihood of the occurrence of disagreement of diagnoses. There was a higher probability if histology was done compared to cases without histology (OR 2.01 (1.36 – 3.23)) and for non-adult animals compared to adults (OR 1.65 (1.14 – 2.38)).

Discussion

The aim of this retrospective study was to underline the value of post mortem examination of ruminants and its benefits for ruminant medicine. Therefore, clinical and pathological diagnoses were compared to present rates of agreement, disagreement and diagnosis specification. Furthermore, influencing factors on both the diagnosis-finding process and the specification of diagnoses were identified.

A major point that should be considered regarding this study is that it was conducted at a veterinary teaching hospital. This might have introduced some bias, as the patient population in this type of institution might only partly be comparable to the one a veterinarian would meet “in the field”. Due to the presence of advanced diagnostic possibilities and specialized staff in such an institution, practitioners might tend to refer a higher number of unusual, rare or otherwise special cases, or animals with a higher economic or genetic value.

The University of Zurich lies in the heart of an intensive dairy region, which is shown by the fact that cattle were the predominant species in the present study. Sheep and goats play a minor role in Swiss agriculture and are often kept as private/hobby animals. This is also reflected in the distribution of the gender of the animals, with a higher number of male goats and sheep, compared to cattle, where most of the male animals go into meat production and, due to their lower economic value, would only rarely be sent to a teaching hospital in case of disease.

The distribution of the primary categories of clinical and pathological diagnoses in all three species provides a good overview of the cases used in this study. Digestive

and respiratory disorders are the leading categories in cattle in this study. On the other hand, udder/teat, reproductive and locomotive disorders play a minor role although multiple studies have revealed the importance of these disorders as causes of losses or disposal in cattle (Clarkson et al., 1996, Esslemont and Kossaibati, 1997, Gardner et al., 1990, Kossaibati et al., 1998 and Østerås et al., 2007). This might contribute to the fact that animals receiving a terminal diagnosis regarding those organ systems in many cases could still be used for meat production. The udder or the affected limb however might still have received a pathological examination, but as a single transmittal would not have shown up in this study due to the exclusion criteria. Thus, as stated above, the majority of cattle used in this study, independently of their age, died or was euthanized due to digestive or respiratory disorders. This confirms the main causes of death of calves and heifers shown in the literature (Gulliksen et al., 2009, Svensson et al., 2003 and Svensson et al., 2006). The high rate of death due to digestive disorders in adult cattle is not surprising, as digestive disorders in many cases stand for severe, untreatable alterations like torsio mesenterialis or ruptured abomasal ulcers that lead to the death of the animal, or to the decision for euthanasia, as soon as the diagnosis is made by the clinician. In sheep and goats, digestive disorders again proved to be the main cause of death, as well as neurologic and urinary disorders, like urolithiasis in male goats.

In the vast majority of cases, both a main clinical and main pathological diagnosis could be established (group A), namely in 81.40% in cattle, 80.22% in sheep and 66.67% in goat. These rates are comparable to rates reported for cats and dogs in other studies (Sacco et al., 2014 and Thomsen et al., 2004). The reason for the smaller percentage in goats is unclear. No pathological diagnosis (group B) was established in 7.42% of cattle, 4.95% of sheep and 7.41% of goats. Those cases show that there are some limitations in the post mortem examination. One problem the pathologist has to face is alterations that are causative of the death or euthanasia of an animal but are no longer visible at the moment of the post mortem examination and cannot therefore be confirmed with complete certainty in necropsy. This especially applies to alterations in the digestive system which accompany displacement of organs, such as abomasal displacement, ruminal tympany or vagal indigestion syndrome, though these alterations might cause detectable alterations in structures like nervous tissue, but are not easily detected in a routine post-mortem examination (Fubini et al., 1985 and Sattler et al., 2000). External influences like

moving the carcass or incipient putrefaction can alter the position of internal organs post mortem, making it difficult for the pathologist to differentiate between pre mortem and post mortem alterations. Another limitation is given with infectious diseases where the causative agent is no longer detectable in the post mortem examination due to autolysis or overgrowth with putrefactive agents, which can potentially mask the original causative agent. The clinician should therefore keep this fact in mind when submitting animals with such a suspected diagnosis, and the time between the death of the animal and the performance of a post mortem examination should be kept as short as possible to avoid negative influences by autolytic processes. In 19 cases, the main clinical diagnosis could not be confirmed by means of pathology. Botulism, tetanus and metabolic disorders such as hypocalcaemia are typical examples, as they leave no pathological alterations in the animal's body. Mistakes or failures of the clinician or the pathologist, such as incorrect transmission of animals, loss or accidental destruction of carcasses or organs, or mistakes in the necropsy application or overlooking and/or failure to examine organs were sporadic causes for missing diagnoses (37 cases out of 2'000). Those failures should be avoided to ensure a good quality of post mortem examination.

No main clinical diagnosis (group C) could be established in 7.43% of cattle, 11.54% of sheep and 18.25% of goats and neither a clinical nor a pathological diagnosis was made in 3.86% of cattle, 3.30% of sheep and 7.41% of goat (group D). These percentages are comparable with the numbers reported for cats and dogs (Schertenleib et al., 2015). In cattle, the number of group D cases is comparable to the results in a study conducted by McConnell et al., 2009, who mentions 4.3%, but uses a smaller number of animals. Again, one has to remember the inclusion and exclusion criteria of cases, as animals that died prior to a clinical examination were not considered. Otherwise, the rate of unsolved cases might have been higher. The majority of those cases were attributed to downers of unknown genesis, neurologic symptoms or weakening of unknown genesis and cases of sudden death after the clinical examination. Out of all cases with no clinical diagnosis the post mortem examination revealed a primary diagnosis in a striking number of cases (group C), namely 65.79% in cattle, 77.78% in sheep and 71.43% in goat. This fact underlines the value of post mortem examination as a diagnostic tool to solve clinically unclear cases. Again, these numbers correspond to percentages found for small animals (Schertenleib et al., 2015).

All cases of group A were analyzed regarding rates of agreement, disagreement and possible diagnosis specification. General disagreement of both primary diagnoses was found in 8.25% (n=113) of cattle, 12.33% (n=18) of sheep and 8.89% (n=8) of goats. All these cases counted as disagreement type II, where the main clinical diagnosis as such was not neglected, but another cause of death unknown to the clinician was revealed in necropsy, meaning that the clinical diagnosis itself was correct in those cases. As explained above, the total number of clinical diagnoses that could not be confirmed in necropsy is the sum of all cases counted as disagreement type I (main clinical diagnosis not confirmable due to mistakes of clinic or incorrect transmittal) from group A (existing main clinical and pathological diagnosis) and cases counted as category V (unsolved cases) from group B (missing main pathological diagnosis but main clinical diagnosis). Therefore the number of unconfirmed main clinical diagnoses is 7.03% in cattle, 12.26% in sheep and 11.00% in goats. These numbers are comparable to values identified for small animals in multiple studies. A recent study revealed disagreement in 16.0% of dogs and 17.9% of cats (Schertenleib et al., 2015), whereas older studies identified values between 14.9% and 39.8% (Dank et al., 2012 and Kent et al., 2004). In ruminants only one study was found that mentioned rates of agreement and disagreement of diagnoses and mentioned 41.0% disagreement in unassisted dead cows and 19.0% disagreement in euthanized cows (Thomsen et al., 2012). However the higher percentages in this study might be attributed to the fact that this study did not take place at a teaching hospital, where more specialized equipment and staff is at hand and cases can be evaluated in more detail, leading to a lower number of unclear cases. Taking into consideration the primary categories of the main pathological and main clinical diagnosis of all unconfirmed or misdiagnosed cases, no category was revealed to be overrepresented and cases were spread over all categories.

To underline the benefit of the post mortem examination a more detailed analysis of the agreement of diagnoses was conducted in this study. Meaningful additional information on a case with clinical pertinence (class 1) was detected in 35.69% of cattle, 26.03% of sheep and 34.06 % of goats, when both diagnoses were at hand. This clearly underlines the value of the necropsy in ruminants as a diagnostic tool to gain information on the case. Minor specifications without clinical pertinence (class 2) were found in 35.18% of cattle, 19.18% of sheep and 33.69% of goats. Total

agreement with no relevant further specification (class 3) of the main clinical diagnosis was found in 20.88% of cattle, 42.47% of sheep and 34.44% of goats. Comparable studies conducted in companion animals identified rates between 36.2% and 85.1%, depending on the type of study. There are only two studies in veterinary medicine known to the author that include diagnosis specification (Schertenleib et al., 2015 and Vos et al., 2005) both of them conducted in small animal medicine. These studies identified rates of specification between 22.7% and 43.8%. Taking into account the species distribution, it is noticeable that the predominant type of specification in cattle is class 1, whereas in small ruminants more class 2 (especially in sheep) and class 3 agreements were found. The exact cause of this contribution is not known, but it is the author's opinion that it might be linked to the distribution of primary categories in each species. As mentioned above, digestive disorders and respiratory disorders were the predominant categories in cattle in general, as well as in all cases counted as class 1 specification. Even with the use of diagnostic techniques like ultrasound, radiography or endoscopy, those organ systems are difficult for the clinician to examine just because of the limitations given by size. Even performing a diagnostic laparotomy just gives a limited overview of the abdominal cavity, meaning that severe alterations can remain hidden to the clinician until they finally reveal themselves in the post mortem examination. In small ruminants however, limitations due to the size of the animal are not so decisive in the diagnostic process, presumably leading to clearer diagnoses by the clinician. Furthermore, neurologic disorders and urinary disorders like urolithiasis play an important role in small ruminant health. In both categories diagnoses are mostly made based on typical clinical symptoms and fewer cases remain unclear, leading to more agreements of class 2 and 3, where the post mortem examination in most cases gives additional information, like the extent or severity of an alteration or confirmation of the diagnosis in general.

Several influencing factors on the presence of diagnoses and diagnosis specification could be identified in this study. Those factors should be kept in mind by the submitting clinician as well as the performing pathologist, to improve the quality of the post mortem examination as well as to demonstrate limitations. No influence was given by the sex of the animal. The type of death of the animal had considerable influence. Animals that died unassisted resulted in a significantly higher number of

cases without a clinical diagnosis and cases without any diagnosis at all. Furthermore, the multivariate analysis proved that the unassisted death of an animal had the greatest influence of all attributes on the probability of a group C (absent main clinical diagnosis but main pathological diagnosis) and D (neither main clinical diagnosis, nor main pathological diagnosis) case, compared to animals that were euthanized. The decision to euthanize an animal is usually setup after an unfavorable diagnosis, based on medical or economic considerations, whereas animals that die unassisted or unexpectedly in the midst of the clinical examination and diagnosis-making process lead to more unsolved cases. However, if a clinical and pathological diagnosis was made in animals that died unassisted, there were significantly higher numbers of cases where relevant additional information was gained in necropsy as well as cases where disagreement of diagnoses was at hand, again revealing the important role of the post mortem examination as a diagnostic tool.

The age of the animal is also an influence, as it could be shown that the probability of getting diagnoses and relevant additional information on the clinical diagnosis is significantly higher in adult animals. Non-adult animals and especially neonatal animals, on the other hand, led to a higher probability of having no clinical diagnosis or any diagnoses at all, as well as higher rates of disagreement or cases where no further relevant information could be found in necropsy. In the author's opinion this result might have several causes. Taking a look at the diagnoses made in young animals and especially in neonates, the major causes of death, besides malformations, are attributed to respiratory disorders and digestive disorders like diarrhea (Gulliksen et al., 2009, Svensson et al., 2003 and Svensson et al., 2006) and are usually caused by infectious pathogens (Blanchard, 2012). If the post mortem examination fails to identify those pathogens the cases usually remain unsolved in the pathologist's view or are counted as cases where no relevant additional information was gained. Adult animals, on the other hand, are usually of higher economic value compared to younglings. In the author's opinion this often justifies the use of advanced diagnostic techniques that lead to clearer clinical and pathological diagnoses. Furthermore, clinicians tend to hold back the decision to euthanize those animals until a definite diagnosis is made, again leading to fewer unclear cases.

One factor, however, which was revealed as having great influence on the quality of pathological diagnoses even in neonatal and juvenile animals is the indication of a

stock problem in the anamnesis of the case. This results in significantly higher numbers of agreement class 1 (relevant additional information) and fewer cases of disagreement. Furthermore, the suspicion of a stock problem proved to be the factor with the most influence on the probability of having a class 1 agreement in total. The intention of finding a clear diagnosis in these cases is especially high on the side of the clinician and pathologist alike, as larger numbers of living animals are affected or there is the additional danger of an epidemic disease, with possible zoonotic potential. However, as most of these cases are caused by infectious diseases or toxic processes, the main function of the necropsy is the gathering and processing of samples for further examinations like bacteriology, virology or toxicology, but still this underlines the important role of pathology in linking institutions in such cases. Histology is the diagnostic tool widely used in pathology. This study could prove its important role in the diagnosis-making process. The performance of a histological examination significantly reduces the number of cases with no pathologic diagnosis and, as the multivariate analysis shows, the factor that most increases the probability of receiving a pathological diagnosis leading to cases of group A. Furthermore, histology plays an important role in the specification of diagnoses and the detection of misdiagnoses, as shown in the univariate and multivariate analysis. If histology is performed and if additional information can be gained by the use of histology, this information is usually relevant (significantly more cases of agreement class 1 and 3, significantly fewer cases of class 2). To conclude, pathologists should be encouraged to use histology as a tool to obtain additional information in unclear cases.

One fact that clearly influences the quality of the pathology examination is the type of necropsy that is performed. Not surprisingly, this study showed strikingly that the number of cases where no pathological diagnosis is reached or cases that remain unsolved or have no diagnosis at all is significantly higher if a partial necropsy is performed, compared to cases where the whole carcass is at hand for post mortem examination, as well as the overall risk of receiving no pathological diagnosis. Furthermore, in cases of group A (both diagnoses at hand) a partial necropsy led to a significantly lower number of cases where relevant additional information could be gained in necropsy and the risk of getting no further information was also strongest with those cases as shown in the multivariate analysis. In addition one has to consider that due to the exclusion criteria only a limited number of partial necropsies were analyzed. Therefore, the number of unsolved cases might be even higher if

account were taken of all cases in which only solitary organs or parts of limbs were sent in for examination. To receive clear and satisfying diagnoses in the post mortem examination, partial necropsies should be avoided if possible.

The influence of the primary category and the pathophysiological basis of the diagnoses were not easy to single out in this study, as the pathological diagnosis was usually defined as the gold standard. However, by taking the main clinical diagnosis as a basis, it turned out that most of the categories had no significant influence on the presence of pathological diagnoses and diagnosis specification. Significantly lower than expected numbers of pathological diagnoses were reached for neurologic disorders, which at the same time had higher rates of disagreement. This reflects the causes of neurologic disorders that cannot be confirmed by means of pathology, such as botulism and tetanus or metabolically induced disorders, and are therefore a clear limitation of the post mortem examination. The influence of accidents in this study is only of limited relevance, as due to the exclusion criteria only limited numbers of cases were considered and furthermore the failure to gain diagnoses in the majority of those cases due to technical mistakes like the accidental destruction of affected parts (e.g. fractured bones) of the animal, or wrong transmittal (e.g. parts of the animal were not sent in). Respiratory disorders and miscellaneous disorders led to more diagnoses than expected and at the same time led to more cases where relevant additional information could be identified. As mentioned, the respiratory system is not easy for the clinician to examine and clear findings are in many cases only identifiable when a necropsy is performed (Sacco et al., 2014 and Scott et al., 2010). For cases counted as miscellaneous disorders the benefit of the post mortem examination is not surprising as those disorders in many cases included diagnoses of unknown genesis, such as abscess formations or peritonitis. Necropsy in those cases often identified the primary underlying pathologic process and therefore gave relevant additional information. In the multivariate analysis, primary categories had no influence at all. A similar picture is given regarding the pathophysiological basis of the diagnoses, where the attributes “multifactorial” and again “traumatic” lead to significantly more cases without a pathological diagnosis. The attribute “multifactorial” in this context mainly stands for digestive disorders like abomasal displacement or vagal indigestion syndrome, which are not easy to identify in the post mortem examination for reasons explained above. The attribute “inflammatory/infectious” on the other hand led to fewer cases without a pathological diagnosis as infectious

pathogens are often identified in further examinations conducted as part of the necropsy. However, due to the set up of this study, the main focus was not on the pathophysiological basis of the alterations. These results are therefore of limited value but further research should be conducted on this topic.

Conclusion

The post mortem examination remains an important diagnostic tool in modern ruminant medicine. Its major benefit lies in the identification of misdiagnoses and the resolution of clinically unclear cases, as shown in this study. The confirmation and additional specification of clinical diagnoses is another major function of the necropsy as a measure of quality control and one of the primary reasons why the post mortem examination is still essential for improving veterinary medical care (Bayer-Garner et al., 2002). Additional information was found in three-quarters of cases and in about 50% of those cases clinically relevant additional information was gained in the necropsy. This underlines the important role of pathology not just as a diagnostic tool but also as a teaching instrument, especially in the background of a veterinary teaching hospital. Factors influencing the quality of the post mortem examination as well as their limitations were identified in this study. The referring clinician as well as the pathologist should keep these factors and limitations in mind to assure good quality of the pathologic examination and reveal satisfying results for both sides. This study is a first step towards demonstrating the value of the post mortem examination. Further, prospective studies should be conducted on the topic, especially focusing on the influence of primary categories and the pathophysiological basis of diagnoses on the presence of diagnoses and their quality. The aim for clinicians and pathologists should be to recognize and propagate the value of the post mortem examination in ruminant medicine.

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Tables

Table 1:

Case overview and species distribution

	Total % (n)	Cattle % (n)	Sheep % (n)	Goats % (n)
Total	100 (2'000)	84.15 (1'683)	9.1 (182)	6. 75 (135)
Sex				
Female	86.55 (1'731)	90.61 (1'525)	65.38 (119)	64.44 (87)
Male	13.45 (269)	9.39 (158)	34.62 (63)	35.56 (48)
Age				
Neonatal	2.45 (49)	2.61 (44)	2.20 (4)	0.74 (1)
Juvenile/ Pre-adult	27.05 (541)	26.74 (450)	32.96 (60)	22.96 (31)
Adult	70.05 (1'401)	70.53 (1'187)	61.54 (112)	75.56 (102)
Unknown	0.45 (9)	0.12 (2)	3.30 (6)	0.74 (1)
Type of death				
Assisted	89.90 (1'796)	90.85 (1'529)	84.07 (153)	84.44 (114)
Unassisted	10.20 (204)	9.15 (154)	15.93 (29)	15.56 (21)
Type of necropsy				
Full	83.20 (1'664)	80.15 (1'349)	98.80 (180)	100 (135)
Partial	16.80 (336)	19.85 (334)	1.10 (2)	0

Table 2:

Presence of diagnoses and species distribution

	A % (n)	B % (n)	C % (n)	D % (n)	A & B % (n)	A & C % (n)	B & D % (n)	C & D % (n)
Total (n=2'000)	80.30 (1'606)	7.10 (142)	8.55 (171)	4.05 (81)	87.80 (1'748)	88.85 (1'777)	11.15 (223)	12.60 (252)
Cattle (n=1'683)	81.40 (1'370)	7.31 (123)	7.43 (125)	3.86 (65)	88.71 (1'493)	88.83 (1'495)	11.17 (188)	11.29 (190)
Sheep (n=182)	80.22 (146)	4.95 (9)	11.53 (21)	3.30 (6)	85.16 (155)	91.76 (167)	8.24 (15)	14.84 (27)
Goats (n=135)	66.66 (90)	7.41 (10)	18.52 (25)	7.41 (10)	74.07 (100)	85.19 (115)	14.81 (20)	25.93 (35)

Table 3:

Causes of missing main pathological diagnoses

Species	Groups A & B % (n)	Group B % (n)	Distribution with in group B				
			I % (n)	II % (n)	III % (n)	IV % (n)	V % (n)
Total	100 (1'777)	7.99 (142)	1.52 (27)	0.6 (10)	3.1 (55)	1.01 (19)	1.74 (31)
Cattle	100 (1'493)	8.24 (123)	1.81 (27)	0,60 (9)	3,28 (49)	1,07 (16)	1,47 (22)
Sheep	100 (155)	5.81 (9)	0 (0)	0 (0)	1.29 (2)	0.65 (1)	3.87 (6)
Goats	100 (100)	10 (10)	0 (0)	1.00 (1)	4.00 (4)	2.00 (2)	3.00 (3)

Table 4:

Overview of primary categories of main clinical and pathological diagnoses

	Cattle		Sheep		Goats		Total	
	C % (n)	P % (n)	C % (n)	P % (n)	C % (n)	P % (n)	C % (n)	P % (n)
Accidents	4.89 (73)	5.02 (75)	1.94 (3)	1.80 (3)	0 (0)	2.61 (3)	4.35 (76)	4.50 (80)
Cardio	5.83 (87)	6.82 (102)	1.94 (3)	4.19 (7)	0 (0)	0.87 (1)	5.09 (89)	6.19 (110)
Digestive	40.66 (607)	42.88 (641)	26.45 (40)	32.34 (54)	26.00 (26)	27.83 (32)	38.62 (675)	40.91 (727)
Metabolic	0.94 (14)	1.07 (16)	0 (0)	0 (0)	2.00 (2)	0.87 (1)	1.03 (18)	0.96 (17)
Miscellaneous	7.77 (116)	4.15 (62)	5.16 (8)	2.99 (5)	6.00 (6)	3.48 (4)	7.44 (130)	4.05 (72)
Musculoskeletal	3.95 (59)	3.61 (54)	3.87 (6)	4.19 (7)	7.00 (7)	5.22 (6)	4.12 (72)	3.77 (67)
Neoplastic	1.81 (27)	3.01 (45)	1.94 (3)	5.99 (10)	9.00 (9)	11.30 (13)	2.23 (39)	3.83 (68)
Neurologic	4.09 (61)	3.21 (48)	22.58 (36)	14.97 (25)	18.00 (18)	18.26 (21)	6.41 (112)	5.29 (94)
Reproductive	2.81 (42)	3.68 (55)	8.39 (13)	8.38 (14)	2.00 (2)	17.4 (2)	3.15 (55)	4.00 (71)
Respiratory	18.89 (282)	16.92 (253)	8.39 (13)	5.39 (9)	5.00 (5)	6.09 (7)	17.28 (302)	15.14 (269)

Sensory	0.13 (2)	0.20 (3)	0.65 (1)	0.60 (1)	0 (09	0 (0)	0.17 (3)	0.23 (4)
Systemic	4.09 (61)	4.95 (74)	6.45 (10)	8.38 (14)	6.00 (6)	6.96 (8)	4.41 (77)	5.40 (96)
Udder/Teat	2.48 (37)	2.47 (37)	0.65 (1)	0.60 (1)	0 (0)	0 (0)	2.17 (38)	2.14 (38)
Urinary	1.67 (25)	2.01 (30)	11.61 (18)	10.18 (17)	19.00 (19)	14.78 (17)	3.55 (62)	3.60 (64)
TOTAL	100 (1'493)	100 (1'495)	100 (155)	100 (167)	100 (100)	100 (115)	100 (1'748)	100 (1'777)

Table 5:

Rates of agreement and disagreement of main clinical and pathological diagnoses

Species	Cases with both diagnoses (group A)	Agreement	Disagreement	Type of Agreement			Type of Disagreement	
				Agr. Class 3	Agr. Class 2	Agr. Class 1	Disagr. I	Disagr.II
Cattle	100 (1'370)	91,75 (1'257)	8.25 (113)	20.88 (286)	35.18 (482)	35.69 (489)	6.06 (83)	2.19 (30)
Sheep	100 (146)	87.67 (128)	12.33 (18)	42.47 (62)	19.18 (28)	26.03 (38)	8.90 (13)	3.42 (5)
Goats	100 (90)	91.11 (82)	8.89 (8)	34.44 (31)	33.33 (30)	23.33 (21)	8.89 (8)	0
Total	100 (1'606)	91.34 (1'467)	8.66 (139)	23.60 (379)	33.69 (541)	34.06 (547)	6.48 (104)	2.18 (35)

Table 6:

Numbers of confirmed and unconfirmed clinical diagnoses

Species	Total (group A and B)	Confirmed	Unconfirmed	No pathological diagnosis (excl. category V)
Cattle	100 (1'493)	86.20 (1'287)	7.03 (105)	6.77 (101)
Sheep	100 (155)	85.81 (133)	12.25 (19)	1.94 (3)
Goats	100 (100)	82.00 (82)	11.00 (11)	7.00 (7)
Total	100 (1'748)	85.93 (1'502)	7.72 (135)	6.35 (111)

Table 7:

Overview of secondary pathological and clinical diagnoses and rates of correspondence and confirmation, respectively

Secondary pathological diagnoses

	Cases with one sec dx % (n)	Cases with two sec dx % (n)	Cases with three sec Dx % (n)	Total number of sec Dx % (n)	Corresponding clinical Dx % (n)	No corresponding clinical Dx % (n)	Clinical Dx specified % (n)
TOTAL (n=2000)	41,90 (838)	11,90 (238)	1,60 (32)	1108	29,78 (330)	61,55 (682)	8,66 (96)
Cattle (n=1683)	41,47 (698)	11,47 (193)	1,42 (29)	920	30,43 (280)	60,00 (552)	9,57 (88)
Sheep (n=182)	40,11 (73)	12,64 (23)	0	96	26,04 (25)	68,75 (66)	5,21 (5)
Goats (n=135)	49,63 (67)	16,30 (22)	2,22 (3)	92	21,27 (25)	69,57 (64)	3,26 (3)

Secondary clinical diagnoses

	Cases with one sec Dx % (n)	Cases with two sec Dx % (n)	Cases with three sec Dx % (n)	Total number of sec Dx % (n)	Dx confirmed in necropsy % (n	Dx not confirmed in necropsy % (n)	Dx not confirm-able in necropsy % (n)	Dx specified in necropsy % (n)	No further examina-tion in necropsy % (n)
TOTAL (n=2000)	29,00 (580)	6,45 (129)	0,50 (10)	719	40,33 (290)	18,08 (130)	8,48 (61)	11,82 (85) 86	20,58% (148)
Cattle (n=1683)	29,53 (497)	6,83 (115)	0,59 (10)	622	39,23 (244)	19,77 (123)	8,68 (54)	12,22 (76)	19,45% (121)
Sheep (n=182)	23,63% (43)	3,85% (7)	0	50	40,00% (20)	8,00% (4)	4,00% (2)	16,00% (8)	32,00% (16)
Goats (n=135)	29,63% (40)	5,19% (7)	0	47	55,32% (26)	6,38% (3)	10,64% (5)	4,26% (2)	23,40% (11)

Percentages regarding the correspondence or confirmation of diagnoses refer to the total number of secondary diagnoses
Percentages regarding the presence of secondary diagnoses refer to the total number of animals for each species

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